Investigating and Proposing a Methodology for Preparing Erosion Types Map by Using Remote Sensing and Geographic Information Systems

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1. Abstract

The erosion features map is one of the basic maps in erosion and sediment studies and watershed management programs. Some methodologies of preparing erosion features map by using RS and GIS were compared in research which took place in the Jajrood sub-basin in north-east Tehran, Iran. In the first phase, four working units' maps were prepared by integrating a) plant cover, geology and slope b) land use, geology and slope c) land use, rocks sensitivity to erosion and slope and d) land use, rocks sensitivity to erosion and land units' layers. In addition to these four working units' maps, three more maps were also evaluated in separating erosion features including e) land units f) sensitivity of rocks to erosion and g) image photomorphic units. The efficiencies of these seven working units' maps are evaluated by 314 control points. For this purpose, by using erosion features of control points regarding field views, surface, rill and gully erosion maps were prepared and compared by crossing them with working units' maps. Results show that method "d" was better than "a", "b" and "c" in providing soil erosion features regarding economic and executive considerations. The accuracy of image interpretation method for preparing surface and rill l erosion maps was 86.4 and 81.0%, respectively. For preparing gully erosion map, image interpretation and integrated layers methods had same accuracy, but integrated layers method had higher precision. Accuracy was 53.0 and 42.9% for methods of land unit and rocks sensitivity resulted in maps not suitable for differentiating soil erosion features. Root Mean Squared Error of erosion maps showed that the error of land unit and rocks sensitivity methods are more than image interpretation and integrated layers methods. The highest coefficient of variation was related to land units and rocks sensitivity to erosion methods and was the least for image interpretation and integrated layers methods. The greatest precision, therefore, were related to image interpretation and integrated layers methods.

2. Introduction

The erosion features map is one of the most important and basic maps in erosion and sediment yield studies (Mohammadi Torkashvand, 2006). In erosion features mapping, field studies and aerial photo-interpretation are perhaps the most precise methods but time consuming and expensive ones (Nejabat, 2003). Therefore, in this study, methodologies of preparing this map are investigated by integrating effective data layers in the environment of Geographic Information Systems (GIS) and processing Remotely Sensed (RS) satellite images and data. Most of erosion and sediment studies have been carried out to provide a quantitative erosion map (Singh et al., 1992; Martinez-Casanovas, 2003; and Ygarden, 2003) and less to preparing an erosion features map. Few studies have been done in providing erosion features maps like GLASOD[1] studies that divided erosion into four categories: water, wind, physical and chemical and prepared a world erosion map of scale 1:5,000,000 (Oldeman et al., 1988, 1991). By applying airborne digital camera orthomosaics and GIS for small-scale studies and field measurements for large-scale studies, Sirvio et al. (2004) have studied gully erosion hazard assessments in the Taita Hills, SE-Kenya,. Detection of distribution and intensity of gully erosion and the main factors affecting gully erosion and its changes during the last 50 years were investigated within the Taita Hills.

Raoofi et al. (2004) attempted to recognize and map erosion in the Taleghan basin in Tehran Province by using image processing techniques. Erosion was categorized into rill and gully erosions and no erosion regions by using images obtained from the fusion of ETM+ bands and Cosmos images. Also a map of ground truth from eroded regions was provided by field observations. Measurements had indicated an approximate 80 percent accuracy for the categorization. Hajigholizadeh (2005) used the ETM+ satellite images interpretation method for providing erosion features maps of five basins in Tehran province, Iran. Results of this research showed that the recognition of surface and rill erosions is very difficult due to image resolution. Therefore, they

[1] Global Assessment Soil Degradation

differentiated gully erosion polygons with low, moderate and high intensity on images and polygons were controlled and corrected by field studies.

The primary objective of this study is to investigate the precision of erosion features mapping using 1) data layers integration, 2) satellite images processing, 3) land units and sensitivity of rocks to erosion and 4) comparing accuracy and precision of different methods.

3. Methods

The Jajrood sub-basin with 162,558 ha located between 51°34′ E and 52°6′ E, 35°13′ N and 35°48′ N was considered for the investigation of erosion features. It extends from northeast to southeast Tehran Province, Iran. The highest and the lowest height of basin are 3000 and 867 m, respectively. Land covers were rangeland, badland, sand borrow, agriculture land and urban regions. Within the basin, different lithic units include pyroclastic stones, tuffs, andesite, shale, conglomerate, gypsum and limestone. Also, Quaternary deposits have covered in the major part of the southern basin particularly in the Varamin plain (47.8% of area basin). Necessary maps such as topographic, geology, plant cover type and land units were scanned and georeferenced. Digital Elevation Model (DEM) was prepared by 1:50,000 topographic digital data, classified slope map-the DEM- derived slope map was classified into eight slope (percent) classes 0-2, 2-5, 5-8, 8-12, 12-20, 20-40, 40-70 and >70 based on Mahler (1979) classification, land use was derived using ETM^+ satellite image and rocks erodibility layer based on Feiznia (1995). According to their sensitivity to erosion, the rocks were categorized in to the five classes.

Seven methods were used to prepare working units' maps of which four methods were to integrate different data layers including a) plant cover type, geology and slope, b) land use, geology and slope, c) land use, rocks sensitivity to erosion and slope and d) land use, rocks sensitivity to erosion and land units’ layers. The other three methods were based on e) land units f) sensitivity of rocks to erosion and g) image photomorphic unit maps. Selection of the data layers was carried out having made exploratory studies in Kan sub-basin (Mohammadi Torkashvand, 2005). Slope, plant cover type, geology, land use and land unit are the important factors in the appearing of the soil-water erosion features. Image processing included radiometric correction, selecting best bands for making color composite with regard to the O.I.F.[2], making principal components 1, 2 and 3, resampling spectral bands and principal components to the panchromatic bands, georeferencing by the nearest neighbour method, making different colour composites using the spectral bands, and linear stretching and filtering in different stages for preparation of colour composites. Finally, all color composites were compared and the best color image was selected for the distinction of erosion features. From DEM, a hill shade layer was prepared and overlayed on a color composite that obtained 3-D view possibility. Regarding the lack of visual distinction of surface, rill and small gully erosions on the satellite image, photomorphic units with attention to color, tone, texture, drainage pattern and other images characteristics, were differentiated on color composite by the screen digitizing methods (Daeles and Antrope, 1977). In this study, erosion features are soil-water erosion types including surface, rill, gully and channel erosions. Different methods were incorporated for classification of surface, rill and gully erosion severity such as Flugel et al. (1999), Refahi (2000), Boardman et al. (2003), Sirvio et al. (2004) and the series of changes are based on experience and expertise considerations (Mohammadi Torkashvand et al, 2005).

A total of 314 points has been considered on color composite images (for field investigation) by classified randomized sampling. A primary polygon was determined for each control point regarding image characteristics. The magnitude of erosion in each erosion feature was investigated in these ground control points and then frontiers of each primary polygon were corrected with due attention to the field views for every one of the surface, rill and gully erosions. Modified polygons with regard to the intensity of each erosion features in the field, were marked. Polygons with same the intensity were combined together and ground truth maps of surface, rill and gully erosions were prepared. The erosion features map obtained from integration of the surface, rill and gully erosions maps. Erosion features maps were crossed by the working units' maps to investigate the ability of each method on separating erosion features. Equation 1 was used for investigating method's accuracy.

$$A = \frac{\sum_{i=1}^{n} Z^*_{(x_i)}\, c_i}{\sum_{i=1}^{n} Z^*_{(x_i)}} \qquad (1)$$

That A is map accuracy or map conformity with actual conditions (percent), $Z^*_{(x_i)}$ is working units' area (ha) and c_i is maximum area of each working unit that is uniform in compared to actual conditions (percent). Root mean squared error of working units’ accuracy and the precision each of method was also obtained.

[2] Optimum Index Factor

4. Results

Table 1 indicates different layers cross operation results in the Jajrood sub-basin. The most and the least numbers of working units were related to map "a" and "d", respectively, and most of the polygons in maps "a", "b" and "c" covered small areas which were not possible to be presented in 1:250,000 maps due to cartographic limitations. The greatest and the least accuracy belong to maps "a" and "c" with 68.3 and 53.4 percent, respectively. The difference of accuracy between maps "a", "b" and "d" is not considerable, but it is significant with map "c". Map "c" has a low accuracy but the greatest precision (high coefficient of variation). A comparison of ground truth erosion features map with map "g" showed that the erosion features uniformity in photomorphic units is more than other methods (because great bulk of data, connected table has not been brought). In the map "g", erosion features are completely uniform in some units even with great area.

Table 2 shows the accuracy of different methods. The highest accuracy belongs to map "g" or image photomorphic units with 72% conformity with actual conditions and 28.3% of the coefficient of variation of working units. At the second stage, map "d" or land use, rocks sensitivity to erosion and land units' layers integration, has the highest accuracy of 66% and 40.5% of the coefficient of variation of working units. The accuracy of land units map "e" and rocks sensitivity map "f" is 53 and 43 percent with 47.3 and 62.8% of the coefficient of variation of working units, respectively. The root mean squared error of working units illustrated in Table 2 shows minimum error in the image interpretation method. The working units' area percentage compared with the basin area in different accuracies is calculated and written in Table 3. Accuracy is less than 50% in 40% of working units' area of rock sensitivity method or map "f". The greatest area with accuracy less than 50% belongs to layers integration method (map "d"). In layers integration method, more area of working units have accuracy more than 50%, but in images interpretation method, more area of working units have accuracy more than 90%.

Table 1 Accuracy and error of crossed layers as the working units' maps in the Jajrood sub-basin

Working Units' Map	Crossed Data Layers	Accuracy (%)	Coefficient of Variation (%)	Root Mean Squared Error (ha)	Total Number of Working Units
A	Slope, Plant cover and Lithology	68.3	34.8	1686.8	902
B	Slope, Land use and Lithology	67.4	40.1	716	436
C	Slope, Land use and Rocks sensitivity	53.4	30.9	1933.8	149
D	Land use, Rock Sensitivity and Land units	66.6	36.5	1732.5	86

Table 2 Accuracy and error for different methods

Kind of Erosion Map	Working units' map	Method	Accuracy (%)	Accuracy coefficient of variation (%)	RMSE* (ha)
Surface	D	Layers integration	78.9	26.2	1185.3
	E	Land units	66.1	38.8	5687.1
	F	Rock sensitivity	59.1	35.9	14510.8
	G	Images interpretation	86.4	20.0	652.0
Rill	D	Layers integration	78.4	24.1	1013.1
	E	Land units	66.8	33.8	5313.2
	F	Rock sensitivity	59.9	31.4	14237.5
	G	Images interpretation	81.0	20.5	1019.6
Gully	D	Layers integration	89.8	17.8	507.5
	E	Land units	82.0	26.5	2466.1
	F	Rock sensitivity	71.9	31.4	9480.8
	G	Images interpretation	89.8	14.0	996.3

Erosion Features	D	Layers integration	66.6	36.5	1732.5
	E	Land units	53.0	47.3	8364.4
	F	Rock sensitivity	42.9	62.8	19605.0
	G	Images interpretation	72.0	28.3	1287.6

* Root Mean Squared Error

Table 3 Percentage of working units' area compared with the basin area in different accuracies

Working units' map	Method	Accuracy (%)			
		< 50	50 - 70	70 - 90	> 90
D	Layers integration	69.2	0.5	5.9	24.4
E	Land units	49.8	50.1	-	0.07
F	Rock sensitivity	39.9	15.5	6.0	38.6
G	Images interpretation	18.9	21.7	44.4	15.0

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